Jet Energy Resolution and Improvements

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SLAC ATLAS Forum, 24-Jan-2007

Introduction (I)

Jet energy resolution has three main contributions:

$$\frac{\sigma(E)}{E} \sim \frac{a}{\sqrt{(E)}} \oplus \frac{b}{E} \oplus c$$

Given a particle-jet energy, what is the distribution of the jet energy measured in the calorimeter. Does not include the contribution of particles outside the cone at particle-level.

- Stochastic response:
  Jet fragmentation
  Sampling fluctuations,
  EM fraction fluctuations per hadron.

- Electronic noise term

- Constant term:
  Dead material, magnetic field,
  calorimeter non-compensation.

- Absolute jet energy scale:
  denominator in sigma(E)/***E***.

Resolution must be ***measured*** in the data,
where there is no access to particle-jets: investigate data-driven techniques.

Jet resolution is crucial in many physics analysis and searches:
investigate ways to ***improve*** it.

Jet Energy Resolution (Dijet balance)

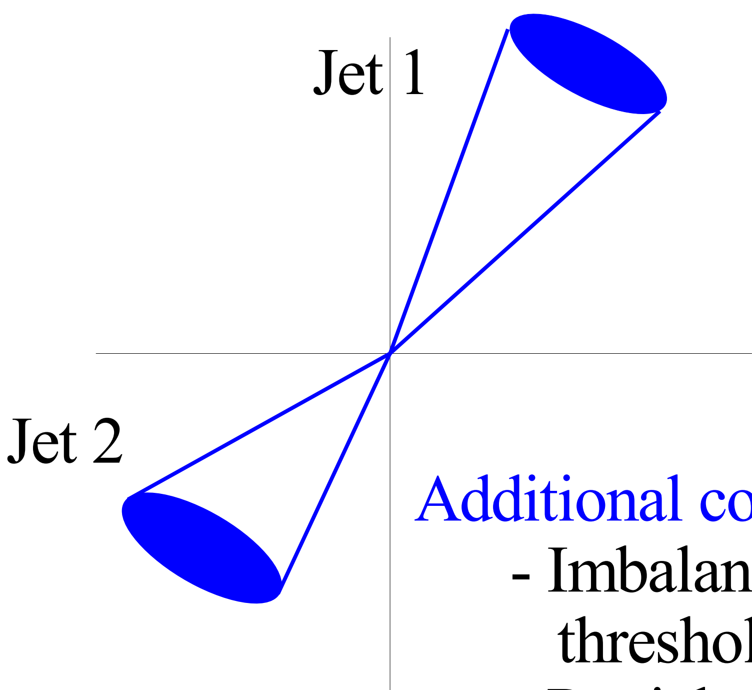
Determination of the jet Et resolution based on energy conservation in the transverse plane.

- 1 primary vertex.
- 2 back-to-back leading jets (DeltaPhi<2.8)
- No other reconstructed jet with Et>10 GeV.
- Both jets in the *same* Eta region.

$$A = \frac{E_{T,1} - E_{T,2}}{E_{T,1} + E_{T,2}}$$

$$\sigma_A^2 = \left|\frac{\partial A}{\partial E_{T,1}}\right|^2 \sigma_{E_{T,1}}^2 + \left|\frac{\partial A}{\partial E_{T,2}}\right|^2 \sigma_{E_{T,2}}^2$$

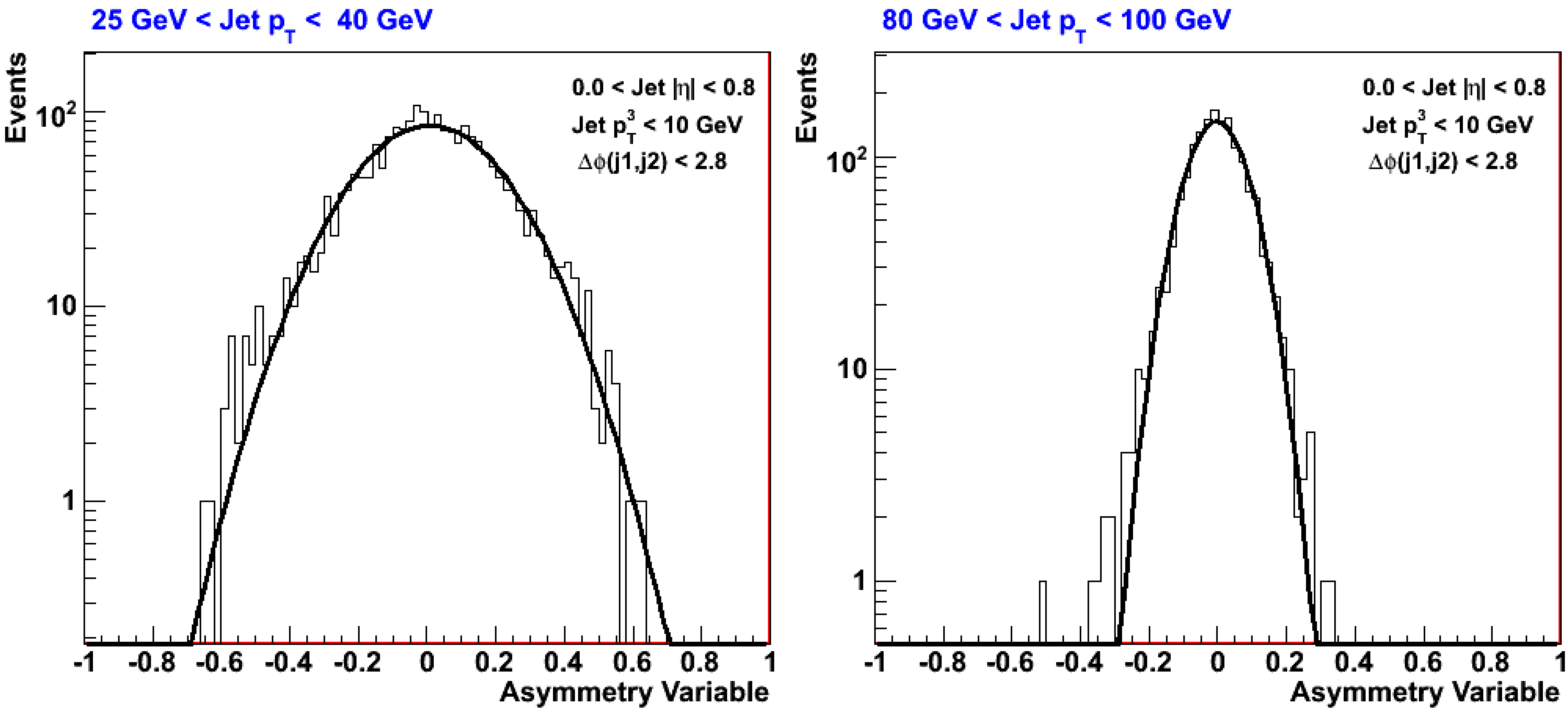
$$\left(\frac{\sigma_{E_T}}{E_T}\right) = \sqrt{2}\,\sigma_A$$



Additional corrections:

- Imbalance due to additional jets below the 10 GeV threshold and soft radiation in the event.
- Particle jet imbalance contribution.

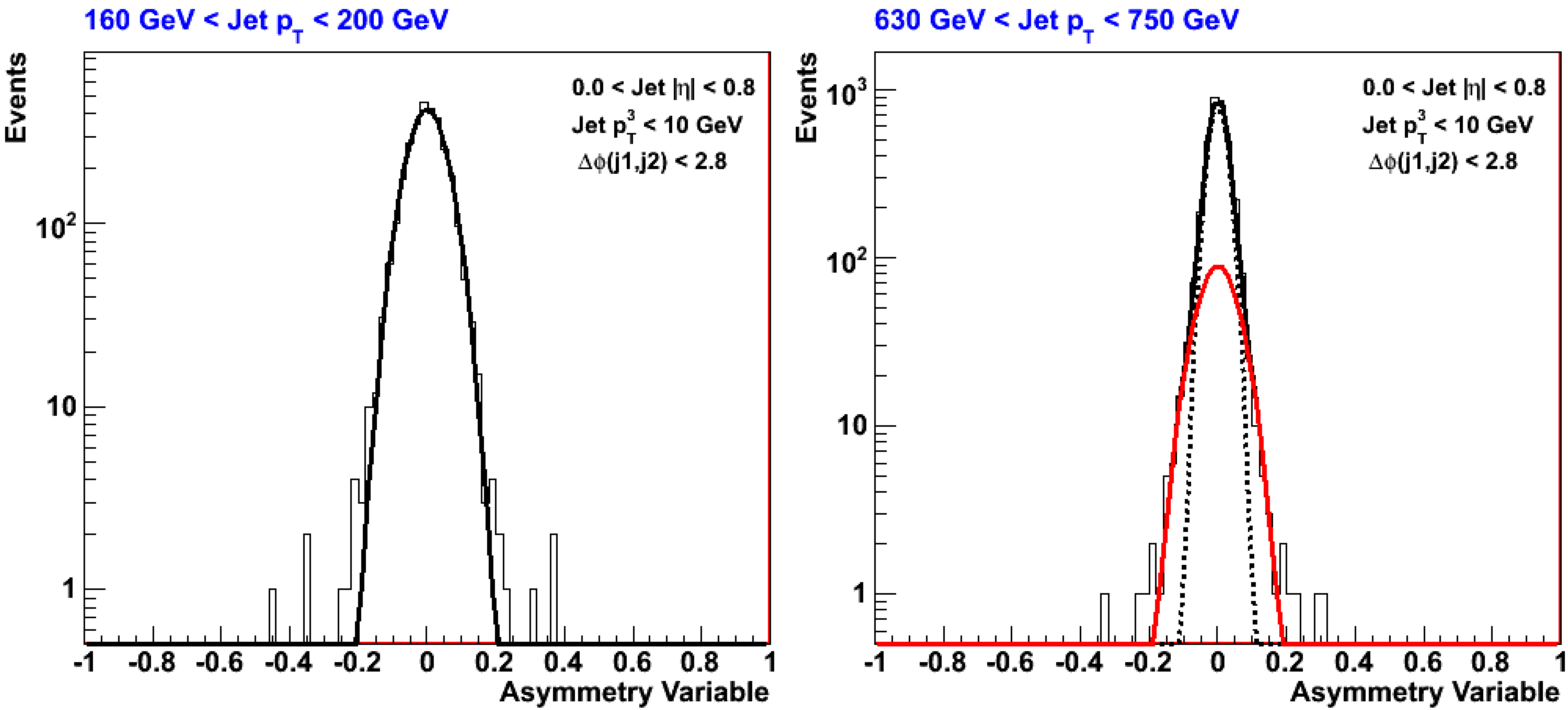
Dijet balance: Asymmetry Distributions



Data sample divided in 4 p_T regions, and 4 eta regions.

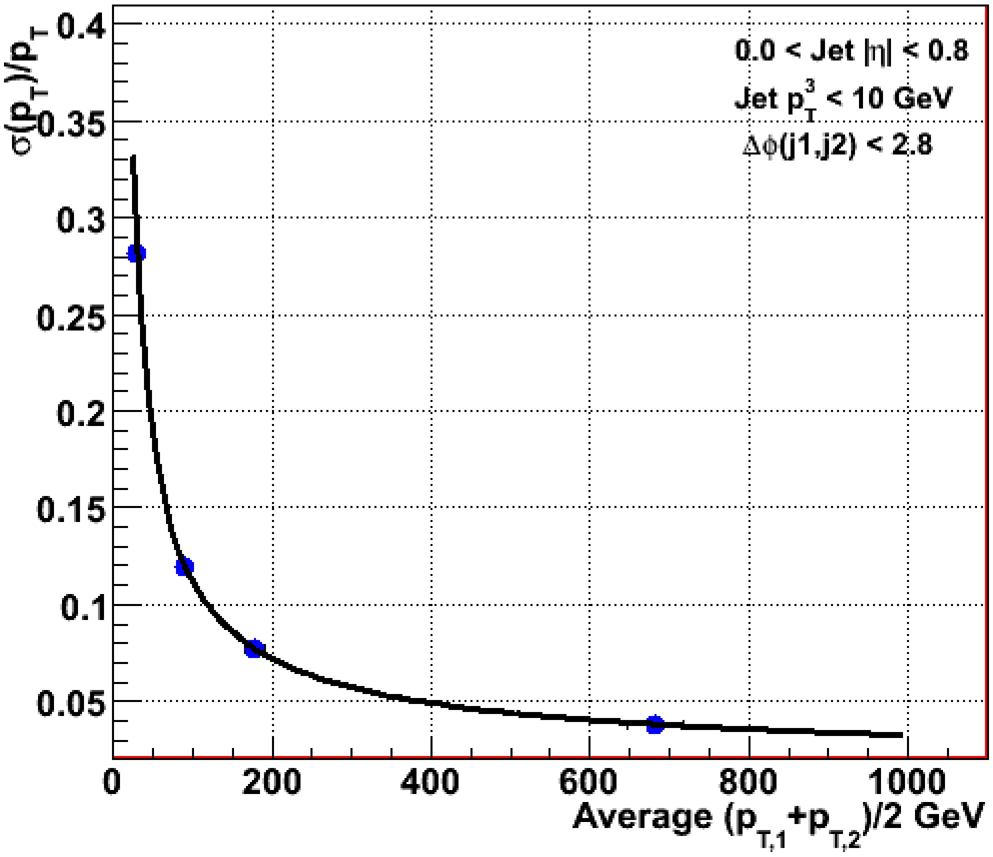
Asymmetry variables fitted with single Gaussians.

Dijet balance: Asymmetry Distributions



Non Gaussian tails in the highest pT bin.

Dijet balance Resolution (Eta<0.8)



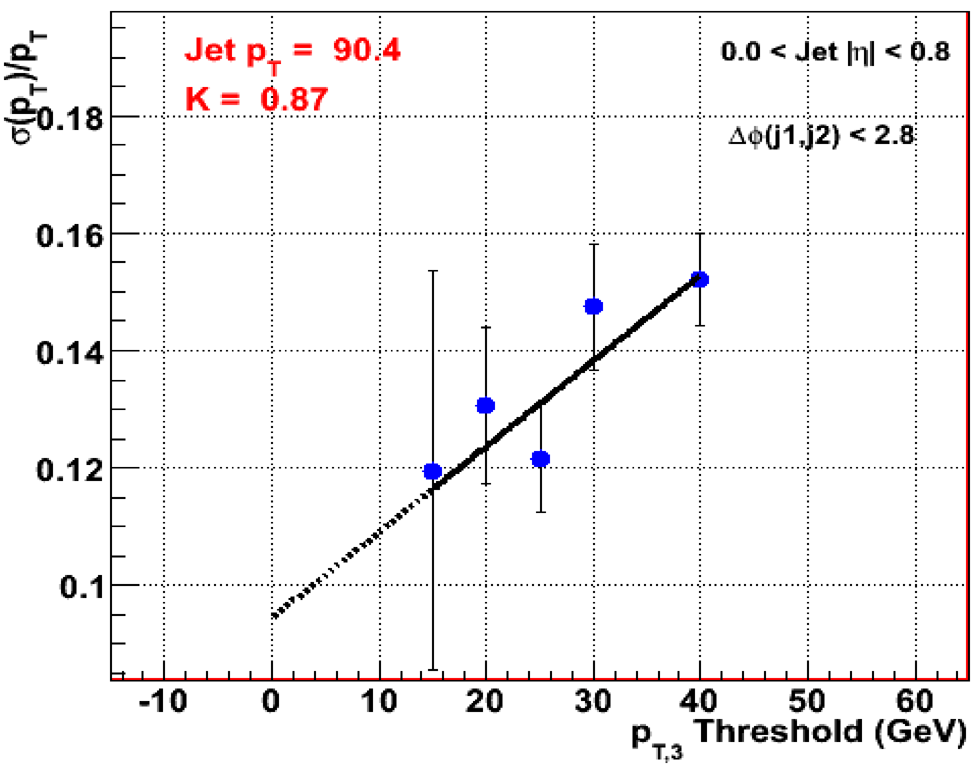
$$\frac{\sigma\ p_T}{p_T} = \frac{0.86}{\sqrt{p_T}} \oplus \frac{7.08}{p_T} \oplus 0.017$$

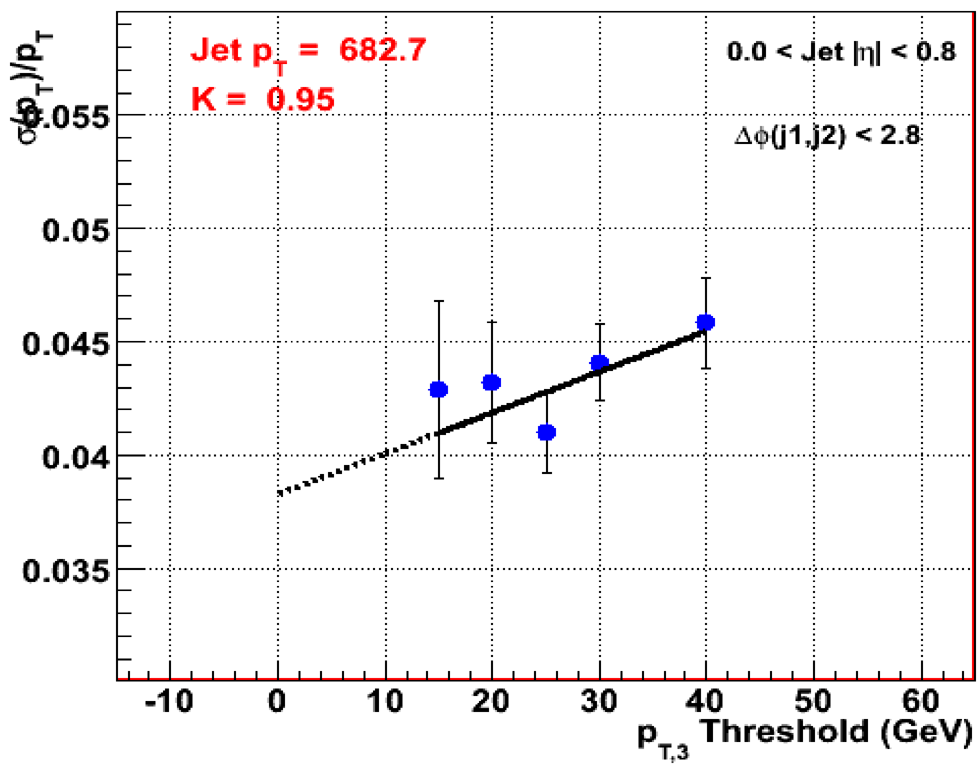
Soft Radiation Correction (I)

Events with soft radiation prevent the two leading jets from balancing in the transverse plane.

Compute resolutions in samples with different third jet cuts: 15,20,25,30,40 GeV

Extrapolate to p_T=0 (ideal Dijet sample)





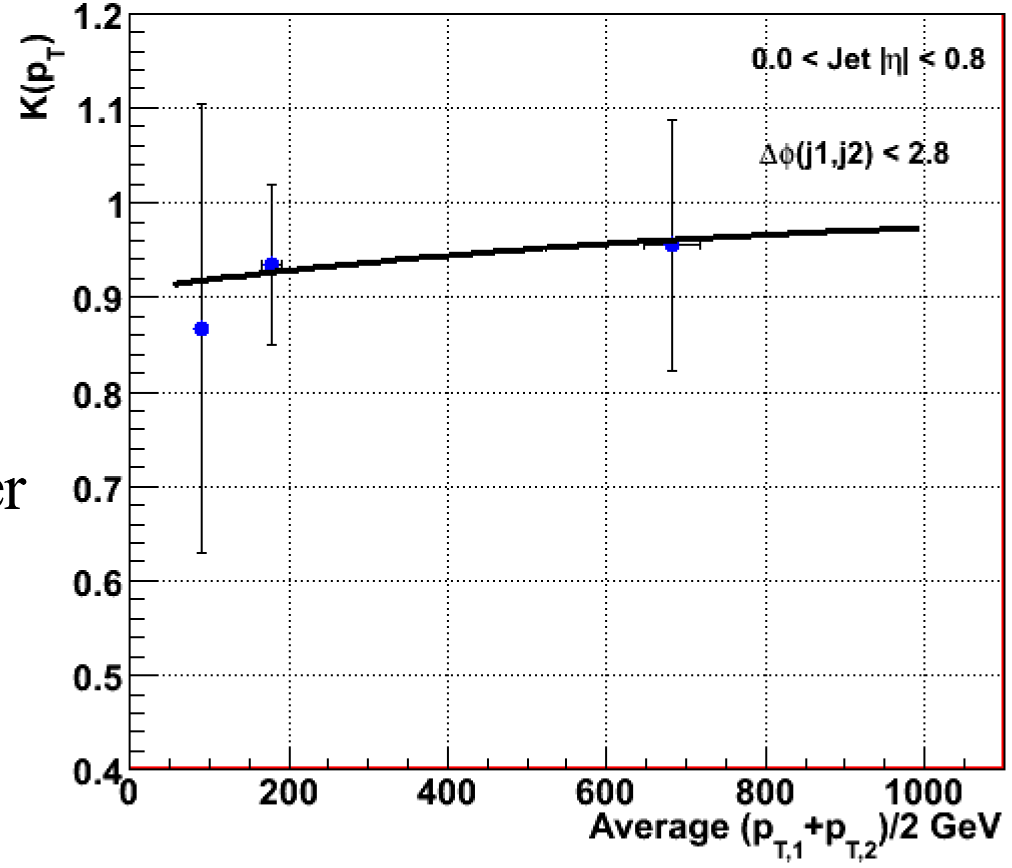
Soft Radiation Correction (II)

$$K(P_T) = \left(\frac{\sigma\, p_T}{p_T}\right)^{th=0\,GeV} / \left(\frac{\sigma\, p_T}{p_T}\right)^{th=10\,GeV}$$

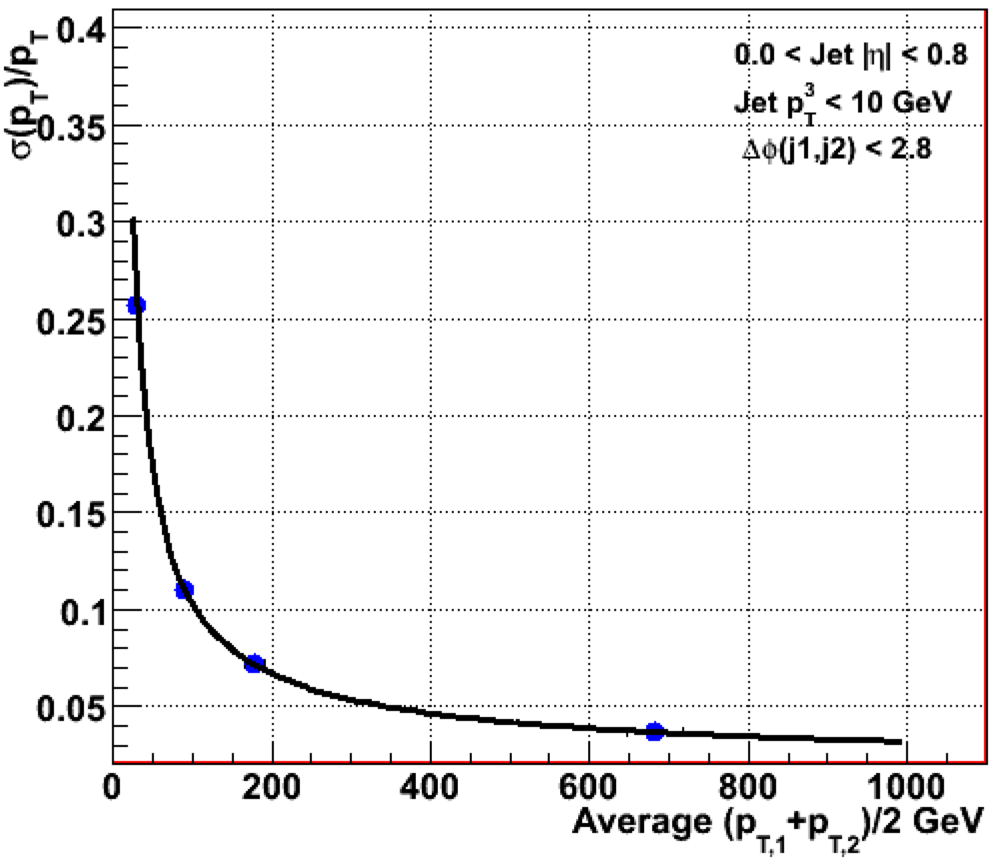
$$\left(\frac{\sigma\, p_T}{p_T}\right) = K\, x \left(\frac{\sigma\, p_T}{p_T}\right)^{th=10GeV}$$

Soft radiation bias should be larger at small transverse energies, and negligible at high p_T:

$$K(P_T) = 1 - \exp^{a - b\, p_T}$$



Resolution after Soft Radiation Correction



$$\frac{\sigma\ p_T}{p_T} = \frac{0.79}{\sqrt{p_T}} \oplus \frac{6.41}{p_T} \oplus 0.019$$

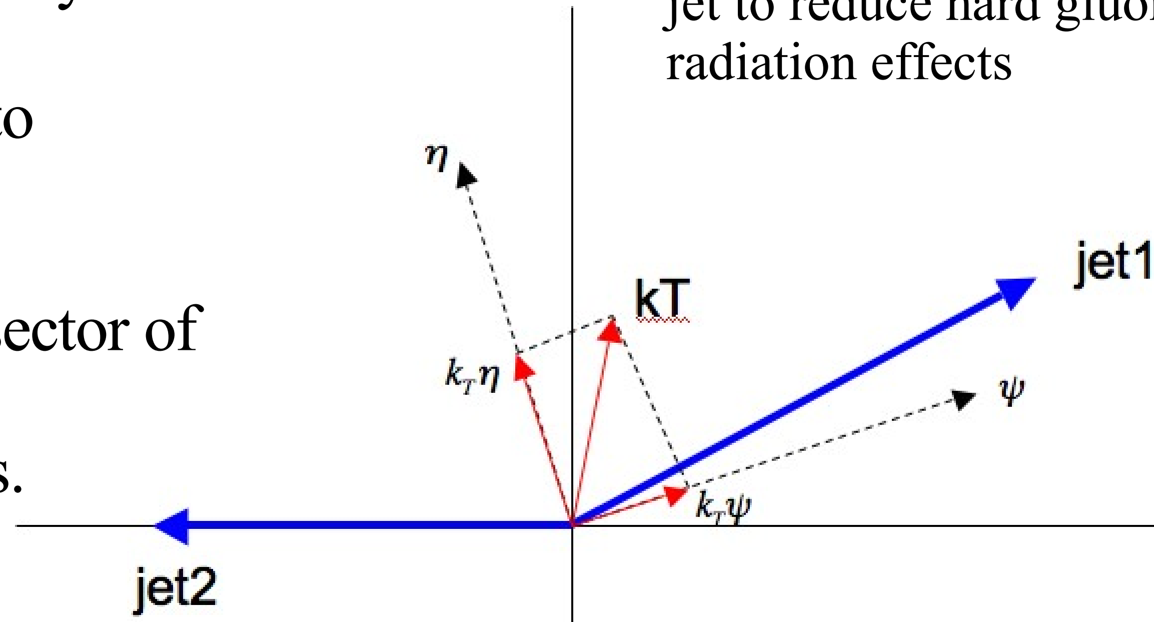
Kt Balance Technique

Method used in CDF, developed by UA2.

Reject events with a third jet to reduce hard gluon radiation effects

Project Imbalance vector kT onto 2 components (psi, eta)

- <u>Eta axis</u>: azimuthal angular bisector of the dijet system.
- <u>Psi axis</u>: orthogonal to Eta axis.



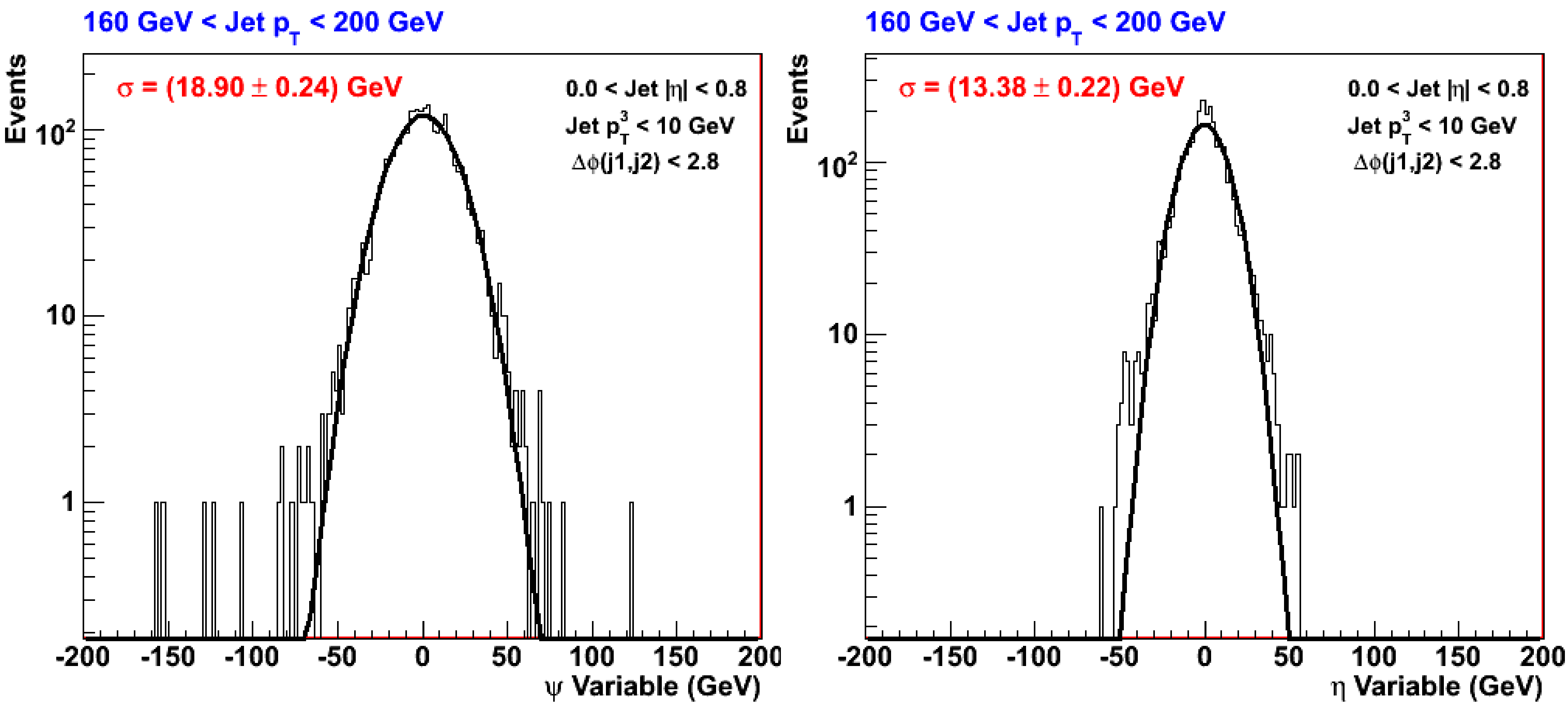
Psi, and Eta components are sensitive to different effects:

Psi distribution: jet energy resolution – gluon radiation.

Eta distribution: jet angular resolution – gluon radiation.

Remove soft radiation contribution by subtracting in quadrature sigma(Eta) from sigma(Psi)

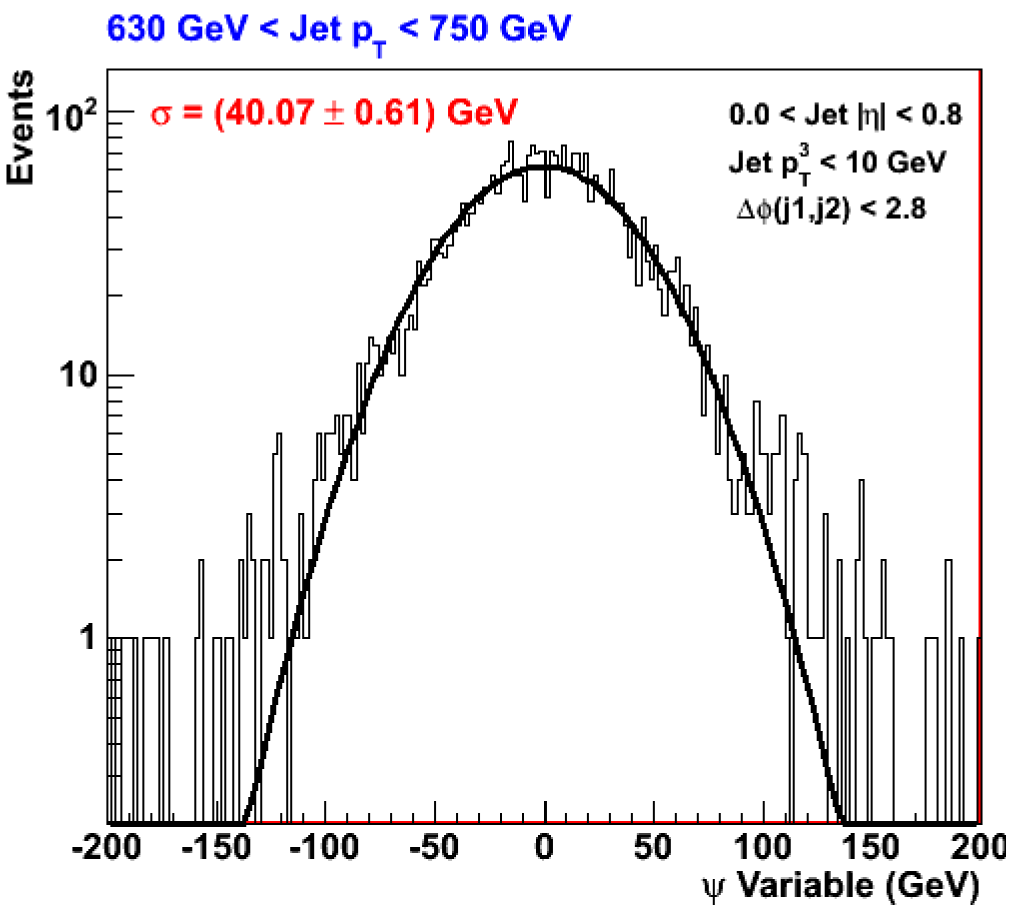
Distributions of the 2 kT Components

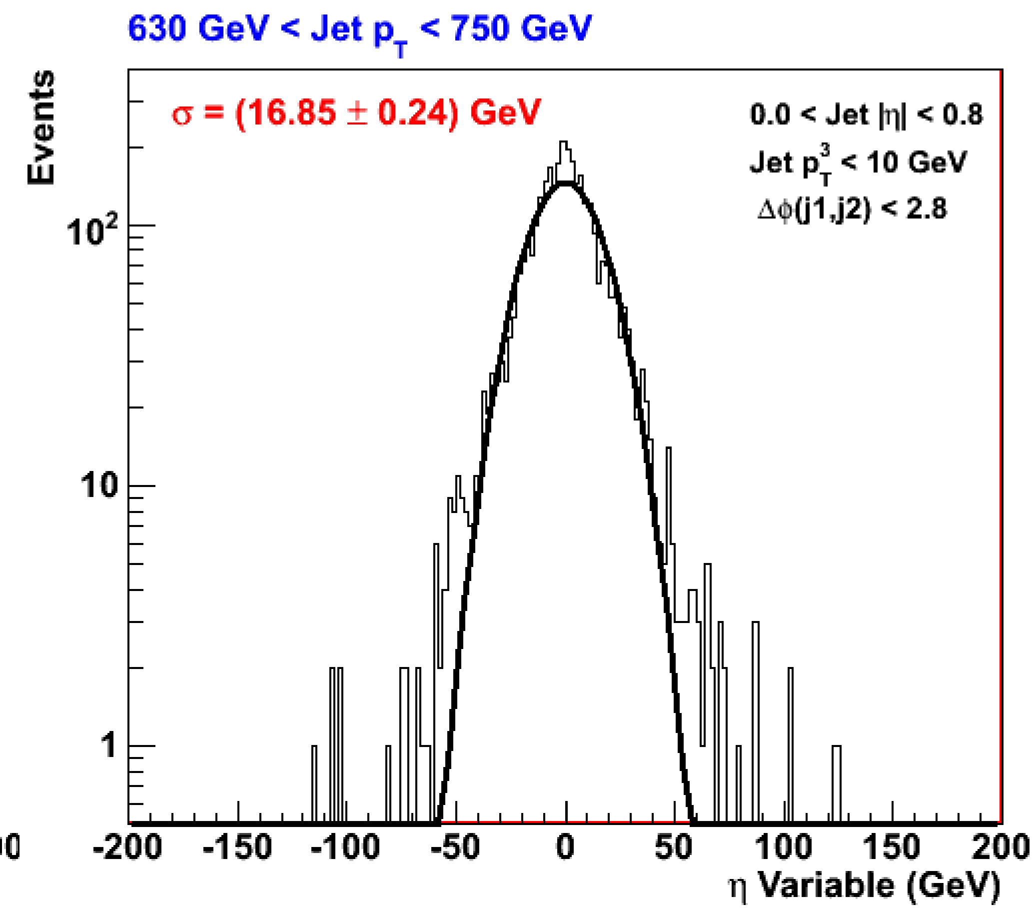


Data sample divided in 4 p_T regions, and 4 eta regions.

Psi and Eta variables fitted with single Gaussians.

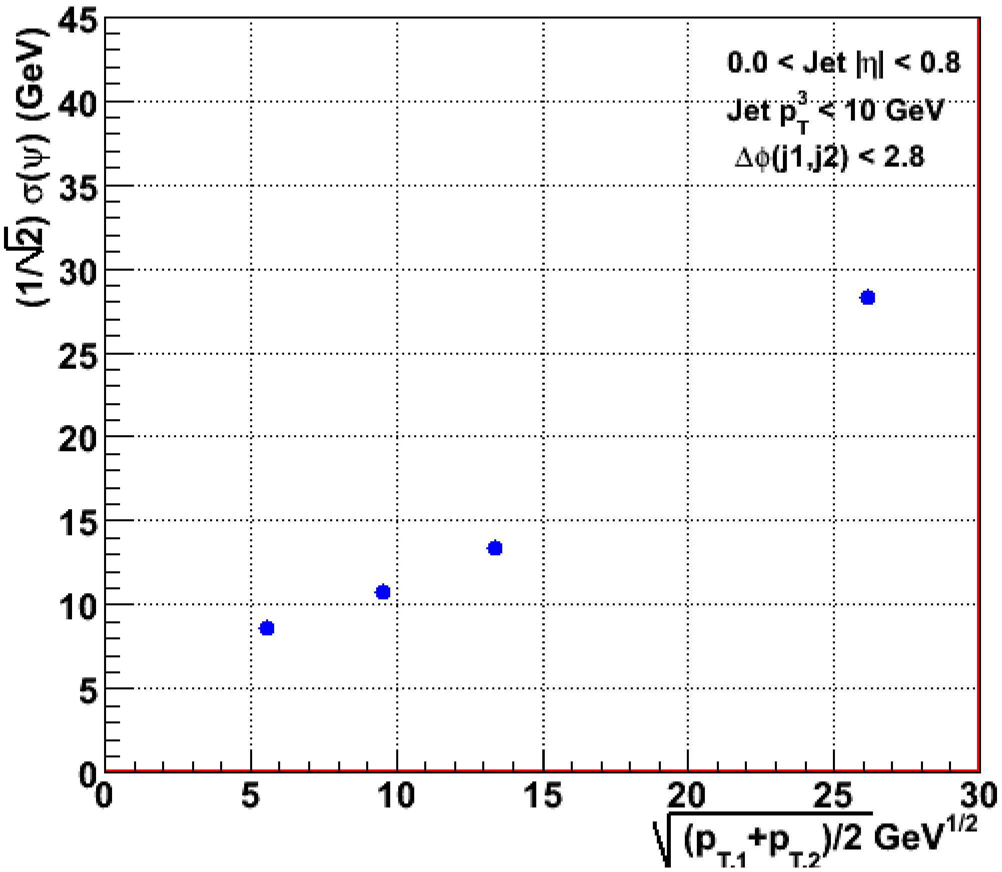
Distributions of the 2 kT Components

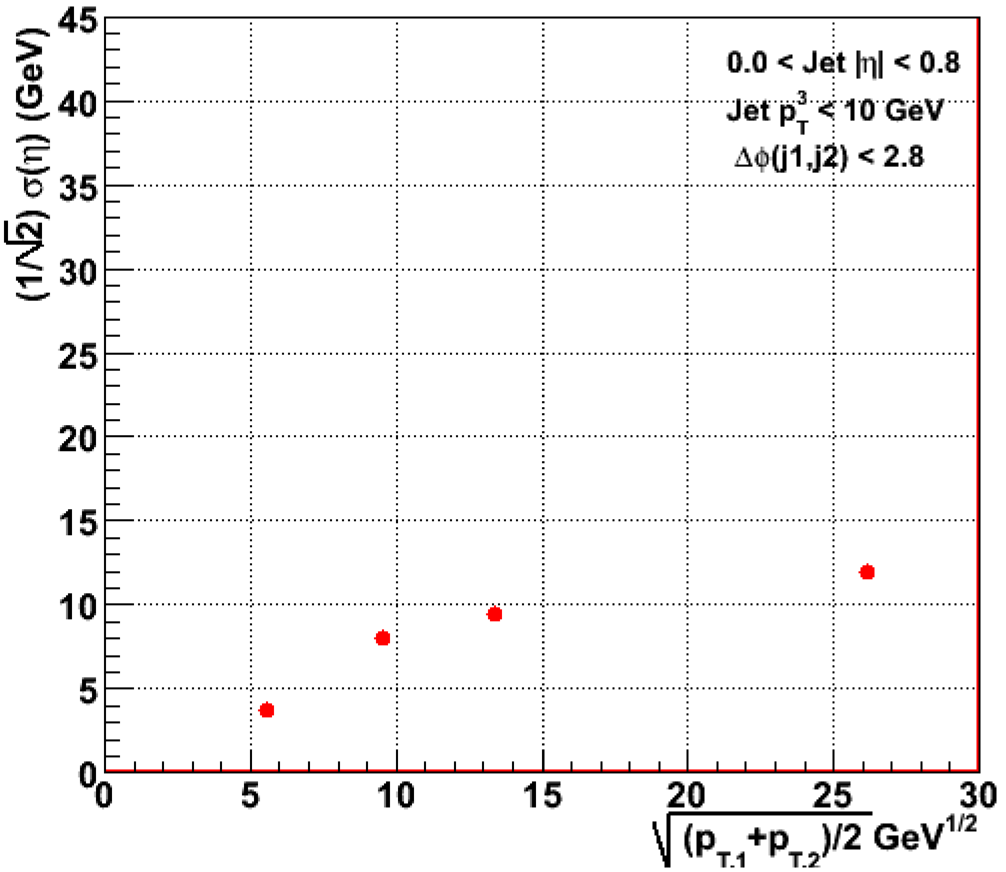




Eta resolution has weaker dependence with energy, as expected.

Resolution of the 2 kT components

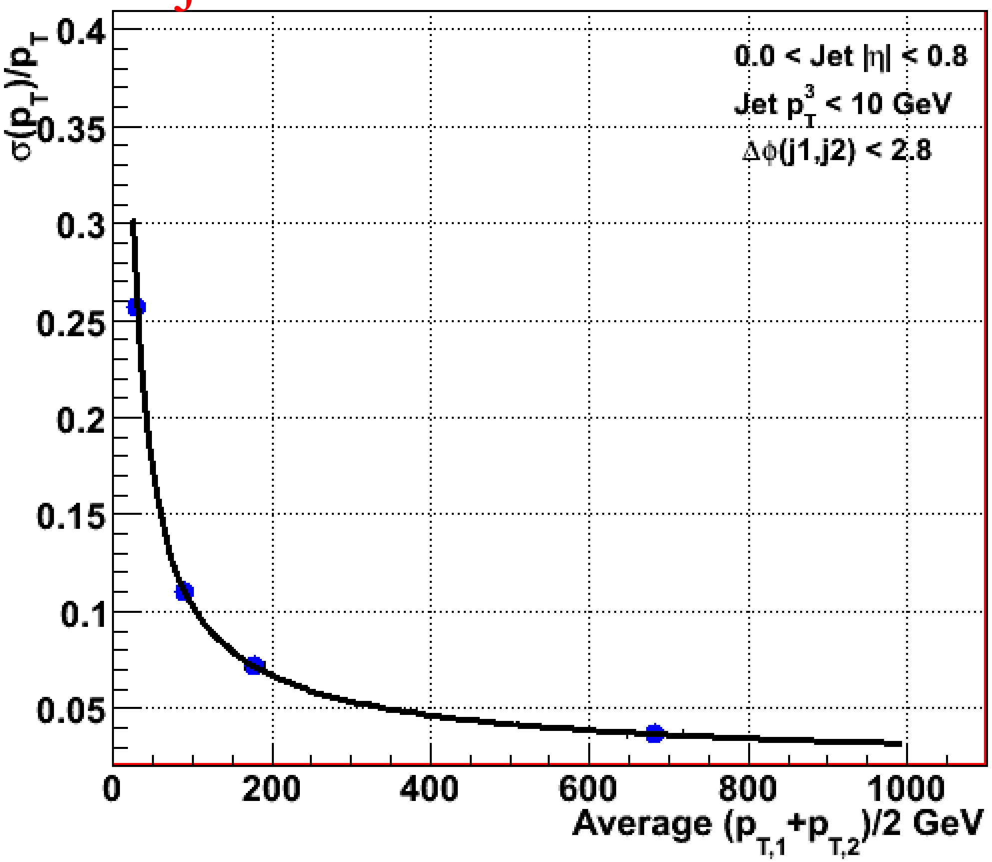




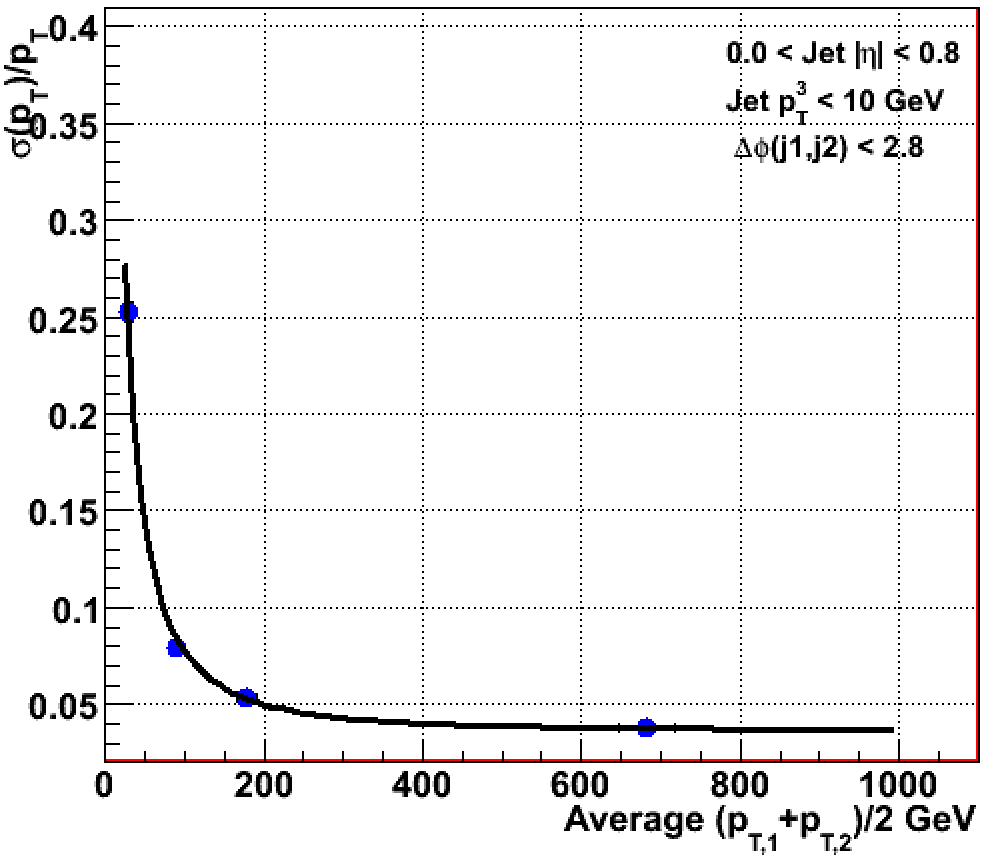
Width of Psi component has an approximately linear dependence with sqrt(pT)
Width of Eta component is more flat, specially at high pT.

Comparison of Dijet and Kt Balance Methods

Dijet balance

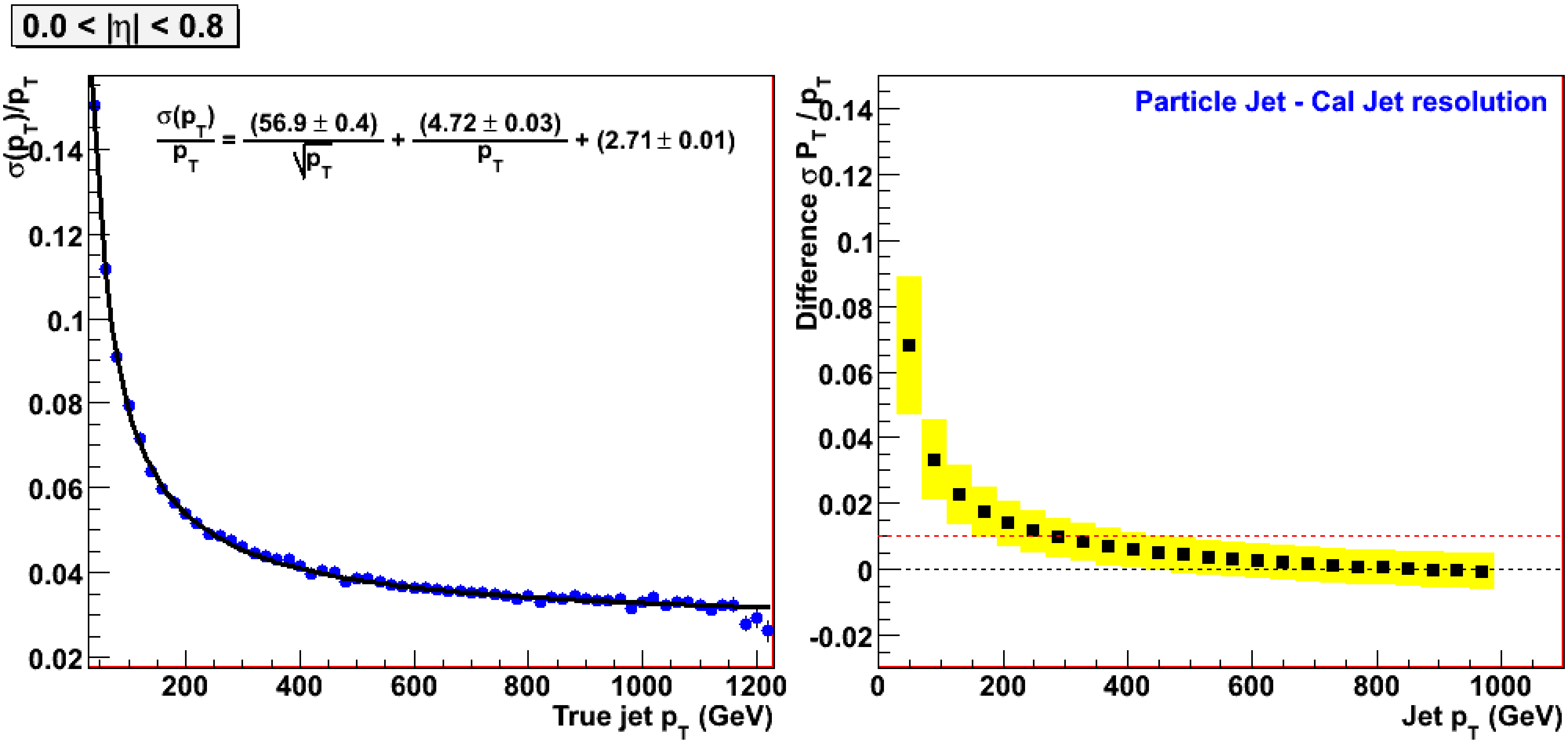


kT



Very preliminary.
Kt technique gives smaller resolution at low pT.

Monte Carlo Closure Test



Compare calorimeter jets with particle jets (straight resolution)
DeltaR(jet,particle)<0.1
Within 1% for pT>200 GeV. Large discrepancies at low pT.

Improving Jet Resolution using Tracks

Tracking provides and independent measurement of energy that can be used to improve the energy resolution.

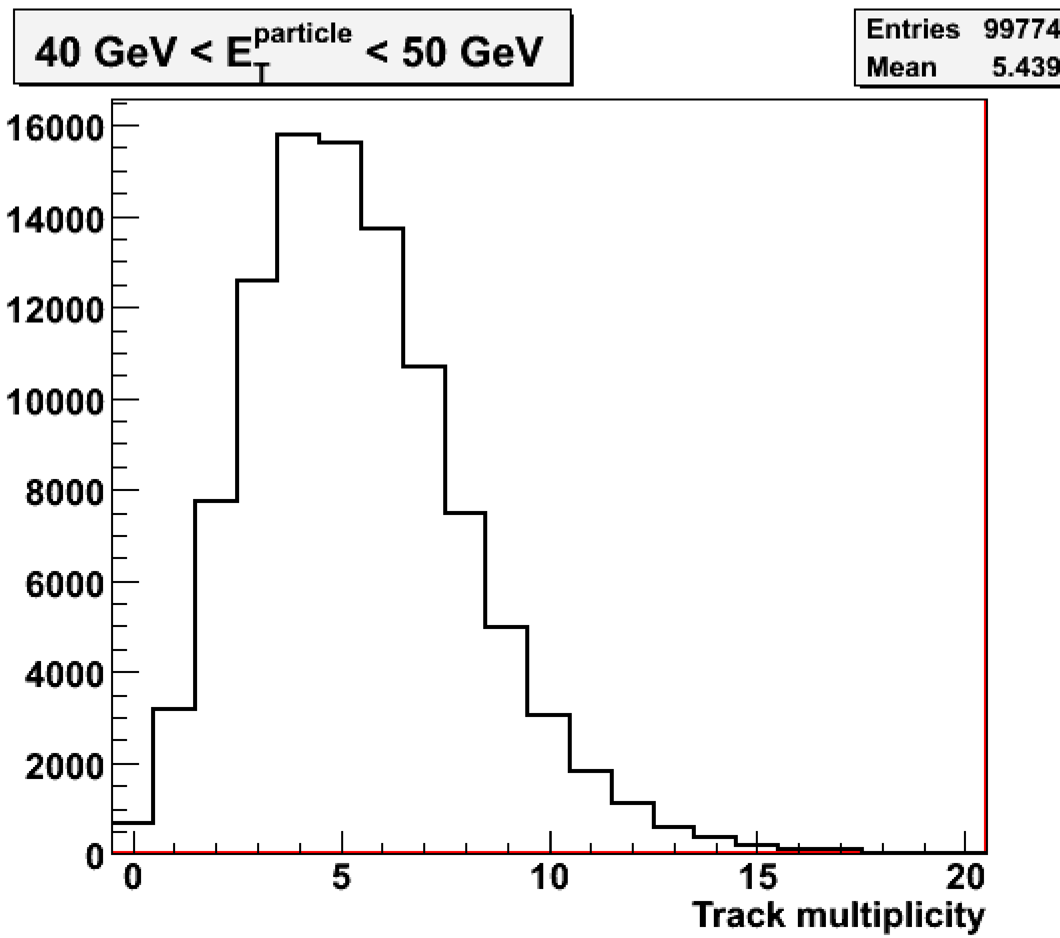
Match Cone 0.4 calorimeter jets with reconstructed tracks:

DeltaR(PV)<0.4

pT> 0.5 GeV

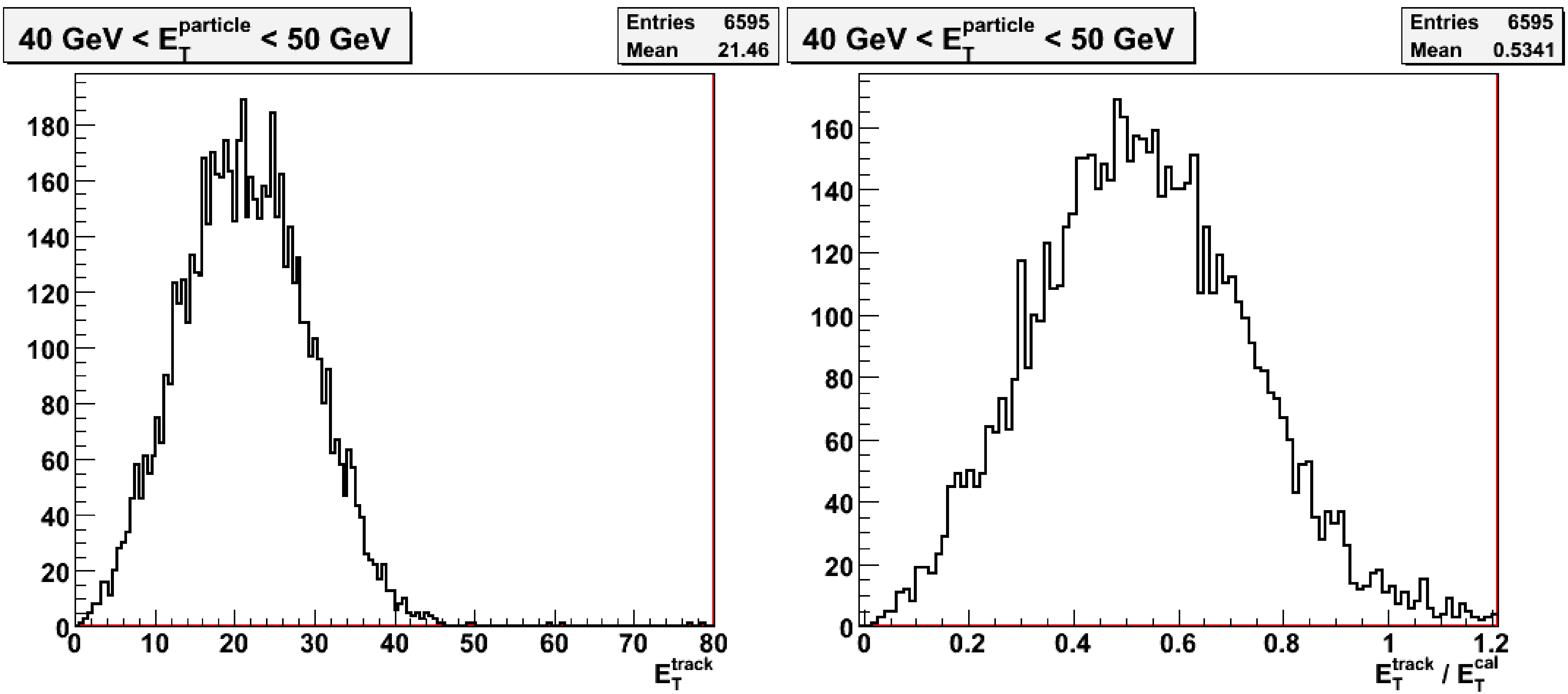
Consider the fraction of charged transverse momentum in jets:

$$f_{trk} = \frac{E_T^{trk}}{E_T^{cal}}$$



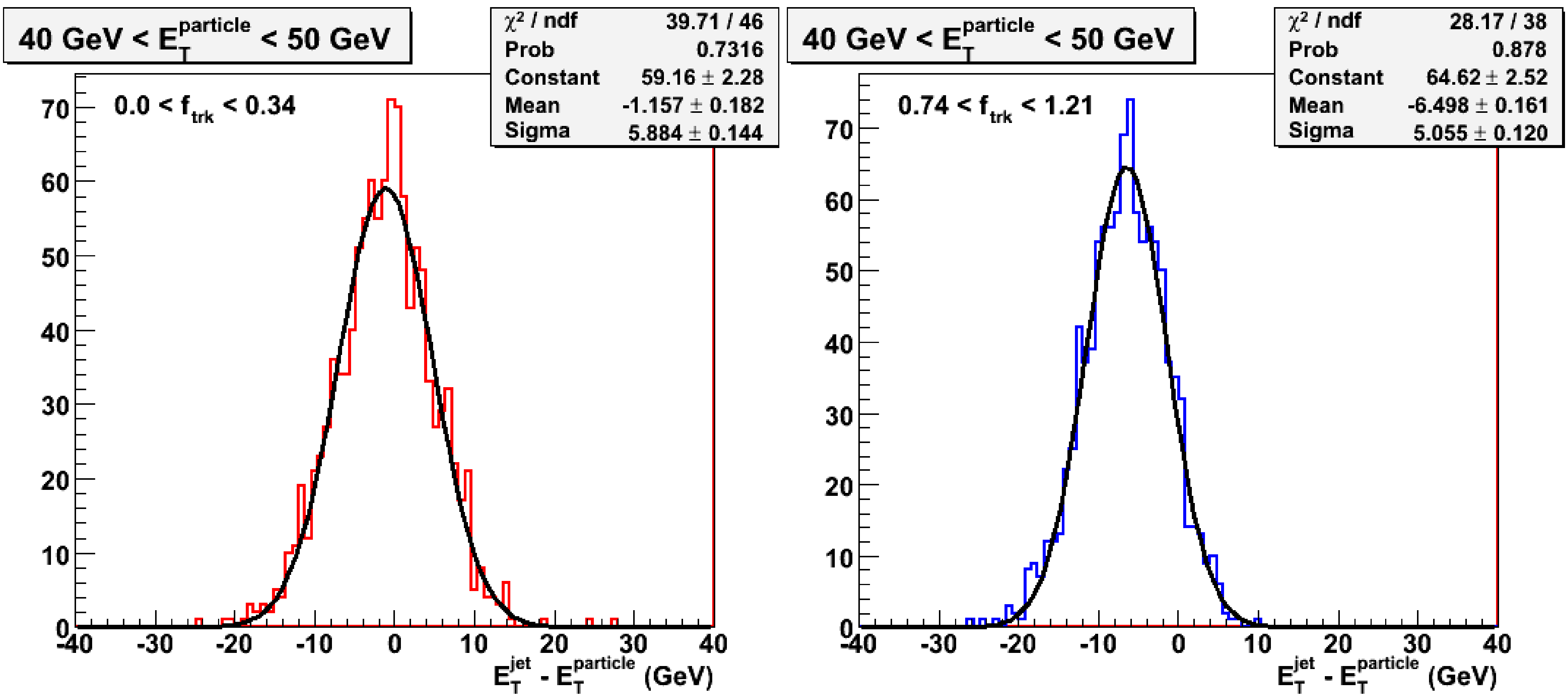
Look at the energy scale of cal-jets as a function of the charged particle composition, and "correct" for differences in scale.

Track Distributions in Jets



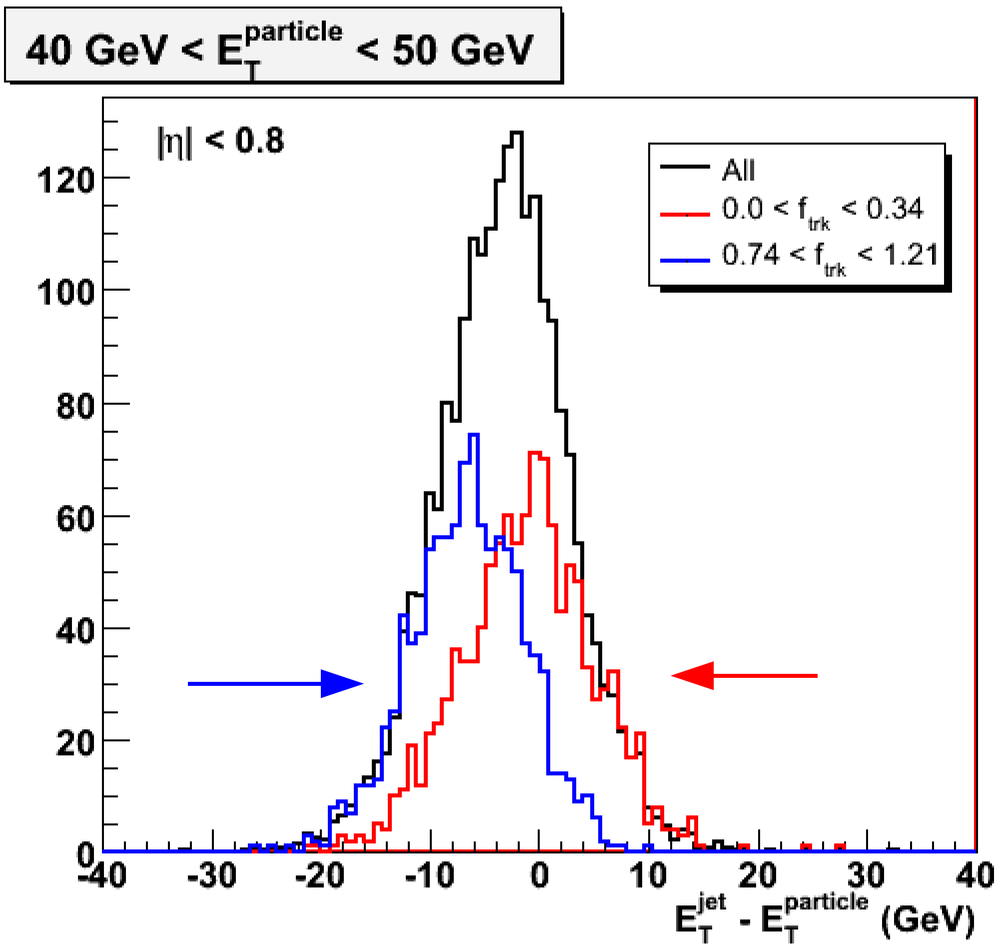
Track selection studies in progress: remove poorly measured and high E tracks

Jet Resolution vs Charged ET fraction



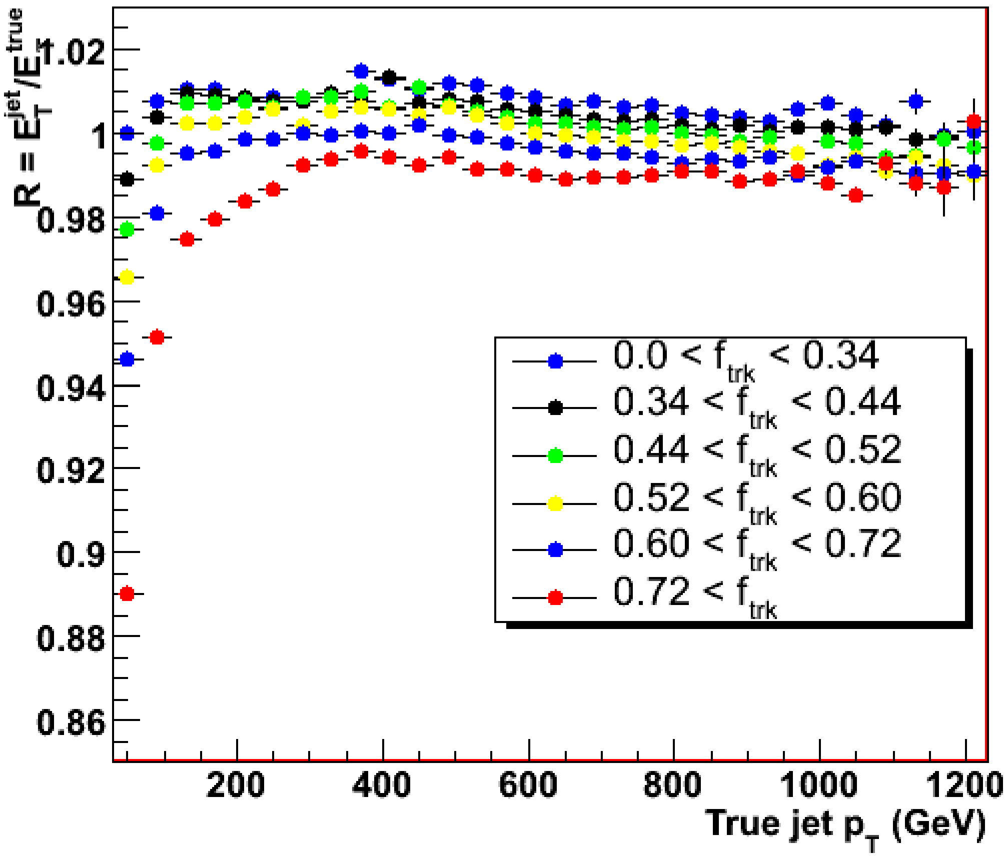
Significant Cal-Jet ***energy scale*** differences as a function of ET fraction.

Jet Resolution vs Charged ET fraction



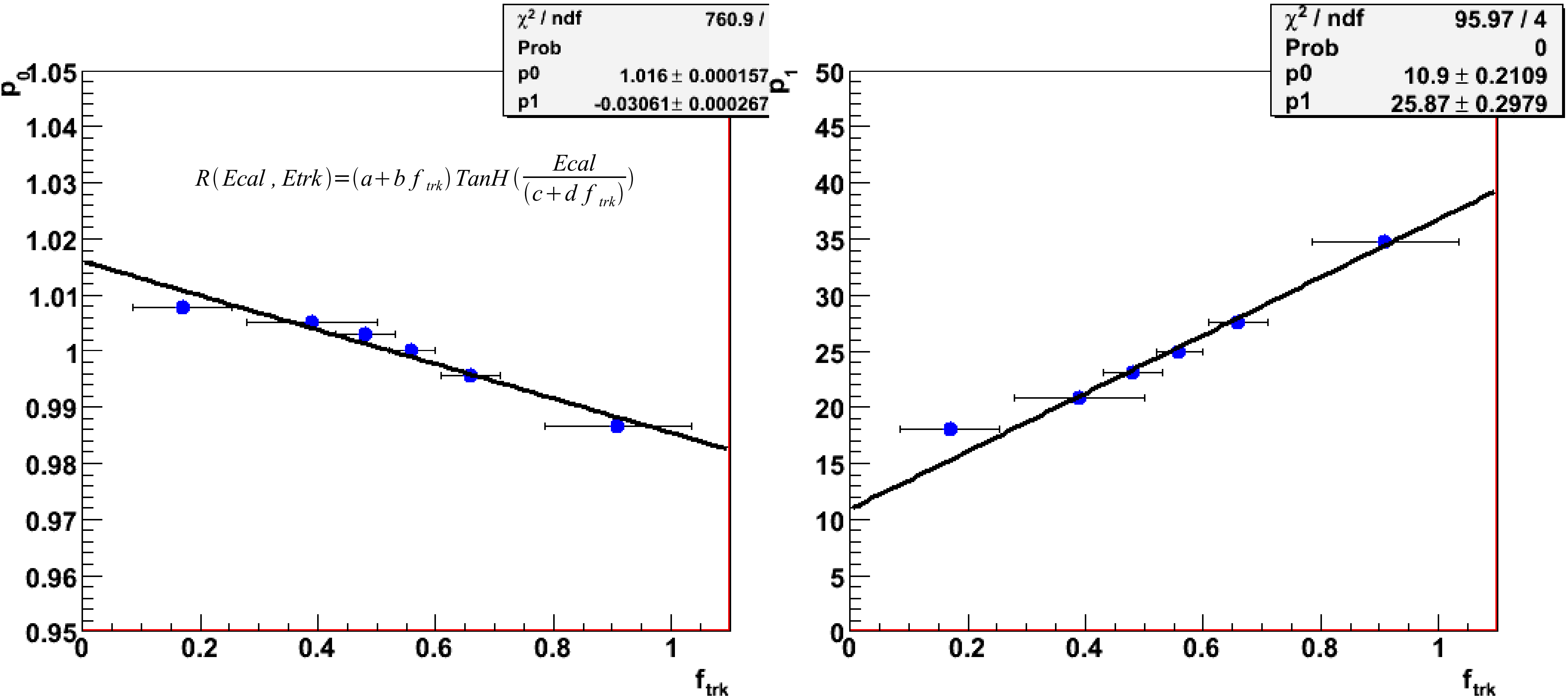
The Cal Jet resolution width can be improved if jets with different f_trk are calibrated such that they have the same energy scale.

Jet Response vs. Charged ET fraction



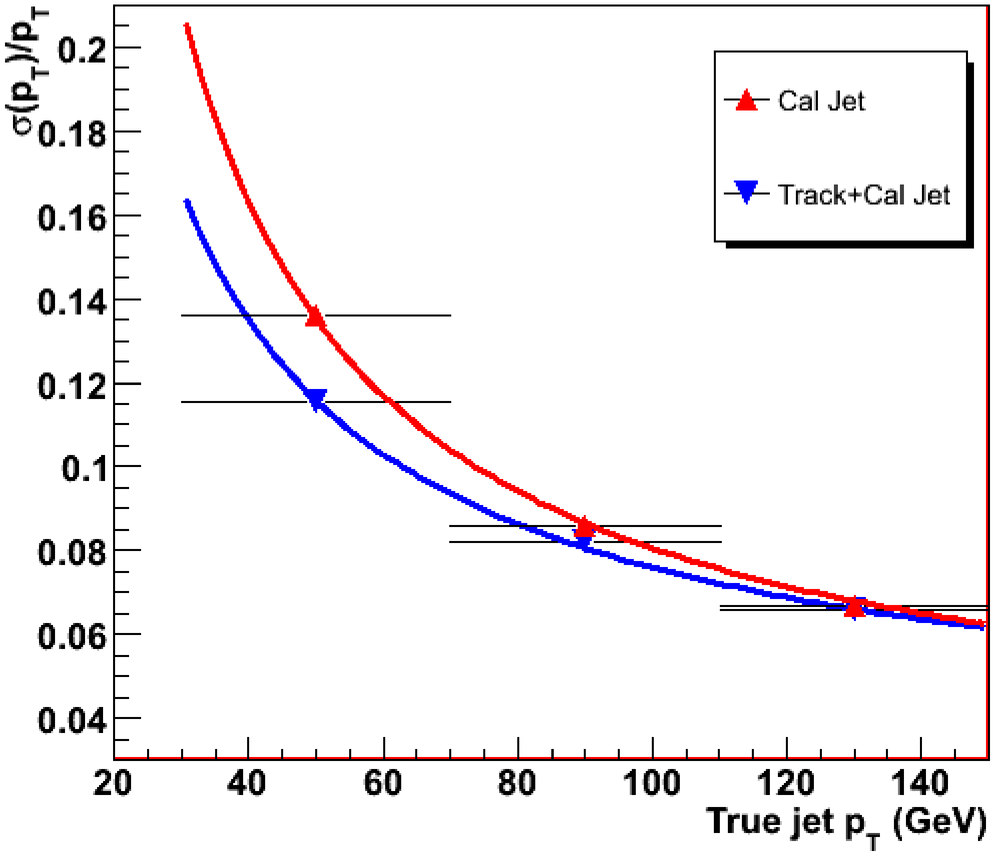
Significant energy scale dependence at low ET (<150 GeV)
Most of the energy shift comes from f_trk>0.5

Jet Energy Scale Correction using Tracks



Fit Jet Energy Response for each f_trk, and derive a track-based response correction: R(Ecal,Etrk)

Track+Jet Energy Resolution Improvement



Jet Resolution is improved because jets with with different charged fraction are corrected to the same energy scale, reducing the overall width.

More than 15% relative improvement at 50 GeV.

Summary and Plans

- First look at 2 data-driven techniques to determine jet energy resolutions: Dijet balance, kT.

  Differences between both methods at low transverse energy.

  Closure test shows that the application of both methods over-estimate the jet resolution at low transverse energy (under investigation)

- Developed an algorithm to improve the jet energy resolution using track information.

  The gain is due to the proper calibration of jets as a function of its charged particle energy content, measured with the tracker (15% @ 50 GeV)

  The next step is to explore the use of correlations between different track variables (to account for jet fragmentation fluctuations) and to optimize the track selection.